Maximize ammonia production cost-effectively

Operating company chooses to revamp the primary reformer to increase capacity of existing unit

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PCS Nitrogen Ltd. (a wholly owned subsidiary of Potash Corp.), operates four ammonia plants at the Point Lisas, Trinidad, facility. The smallest unit, the No. 3 ammonia plant with a nameplate capacity of 750 stpd was built in 1965 for Collier Carbon & Chemicals, Brea, California. In 1994, the plant was relocated to Point Lisas, Trinidad. Over time, the plant capacity was increased to 830 stpd through minor modifications—mostly to the back of the ammonia synthesis loop. Previous expansion studies showed that further rate increases were economical due to favorable natural gas (NG) costs in Trinidad. Likewise, new developments in ammonia converter technology would improve operating costs of this older unit. However, these studies also identified the primary reformer as a major bottleneck. This case history explores the planning and design stages used to revamp the primary reformer of the No. 3 ammonia unit.

PROJECT CHALLENGE

The plant's desired target expansion for Phase 1 was to achieve 1,050 stpd (a 26.5% increase in capacity) and a second phase of extended capacity, which would be in part determined by the success of this Phase 1 expansion. The project team recognized that modification was a step change and would entail careful planning especially since most of the work would be coordinated within a short well-planned turnaround. To avoid potential problems, the project execution was broken into major activities:

- Process simulation and design
- Equipment upgrades, changes and additions
- Pre-shutdown work
- Shutdown work.

Overview—primary reformer. The primary reformer is a twin cell terrace wall reformer with 136 5-in. ID catalyst tubes arranged 68 per cell in a staggered configuration. Gas turbine exhaust (GTE) supports the combustion air requirements of the burners. The burners fire a combination of natural gas and waste gas from the ammonia synthesis loop.

Currently, desulfurized natural gas and steam are preheated in the mixed feed coils located in the hip section of the two radiant cells. Auxiliary burners located downstream of the coils provide additional heat for the remainder of the convection coils. The convection section contains natural gas, process air, steam superheat, steam generation and boiler feed water preheating coils. Two 100% induced-draft fans, located atop the convection section, provide the flue gas exhaust (Figs. 1 and 2).

Recent operating history on the primary reformer indicated that, at 830-stpd capacity, reliability had been unsatisfactory with respect to:

- Frequent failure of catalyst tubes and outlet pigtails
- Hot spots occurring in the outlet transfer line due to refractory cracks.

Process simulation. After screening available process technologies to increase ammonia production, PCS Nitrogen selected a process licensor to review the overall plant design and economics with a combustion equipment company; both worked in tandem and focused on the primary reformer and ancillaries.

FIG. 1 Pre-revamp view of the primary reformer.

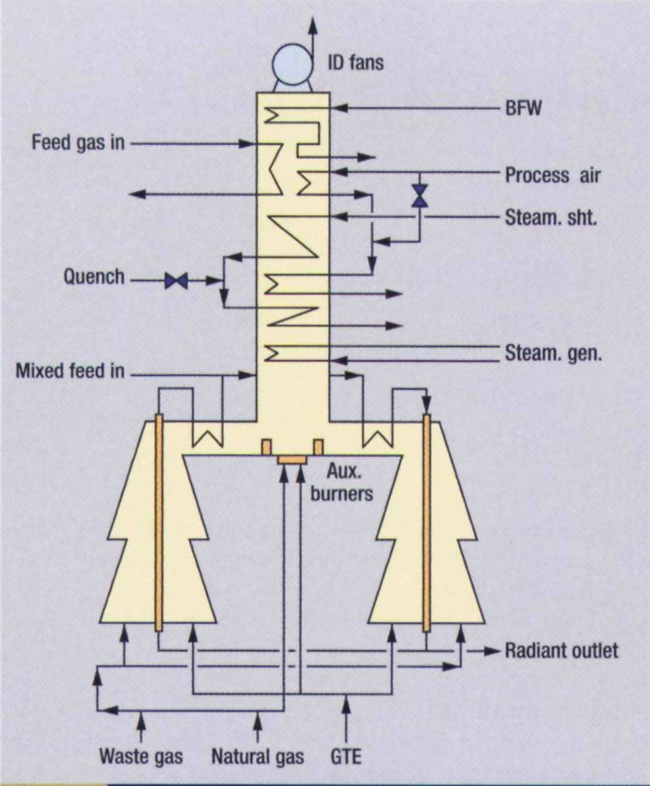

FIG. 2 Schematic of the primary reformer.

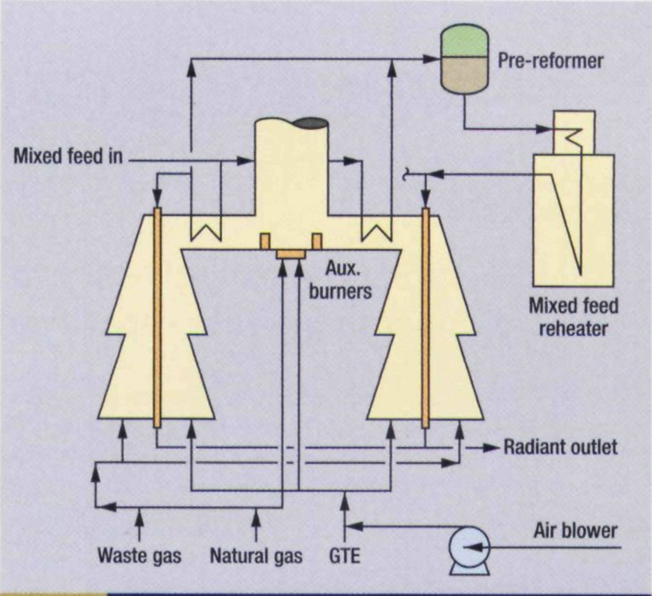

FIG. 3 Revised process scheme with the performer to support additional capacity.

TABLE 1. "Best fit" parameters of the primary reformer

Primary variable	Secondary variable
Process side flows	Furnace heat release (±5%)
Process side inlet temperatures	Process side outlet temperatures (±5°F)
NG composition	Stack temperature (±10°F)
Waste gas composition and flow	Excess oxygen (±0.5%)
CH_4 slip	
Reformer outlet pressure	
GTE composition and temperature	

TABLE 2. Catalyst tube revisions for the primary reformer

	Existing	Post-revamp
Tubes: Material	HK-40	HP-Micro
ID, in.	5	5
Min. sound wall, in.	0.461	0.470
Number per cell	68	76
Total	**136**	**152**
Arrangement	Staggered	Inline

TABLE 3. Reformer heat balance—existing unit and post-revamp

	Existing	Post-revamp
Heat absorbed, MMBtu/hr		
Radiant	115.1	159.4
Convection section	173.8	181.9
Total	**288.9**	**341.3**
Heat released, MMBtu/hr		
Waste gas	56.7	23.5
Natural gas	203.9	290.0
GTE	85.1	85.1
Total	**345.7**	**398.6**

A complete model of the primary reformer comprising both the radiant and convection zones was developed from existing plant operating data as well as information taken from previous plant performance testing. In view of the complexity and inter-dependency of the various parameters considered in the model, closure was arrived based on a "best fit" of certain primary (fixed) and secondary (floating) variables. To make the model meaningful, a maximum tolerance was applied to each of the secondary variables, as listed in Table 1.

Once the baseline model results were approved by the plant personnel, the model was then integrated with process inputs to increase unit capacity. For the capacity simulations, the primary reformer was evaluated for changes required in the radiant section, convection section, steam system, burners and induced draft fans. This was a critical phase; these simulations would determine which equipment and materials could be re-used and those items that required upgrading. From process optimization studies, the process licensor required that a pre-reformer would be required for the new design capacity (Fig. 3).

REFORMER UPGRADES AND CHANGES

As expected, based on the final process scheme adopted, the primary reformer required extensive modification. The target guidelines for the changes were:

- Pressure drop across the primary reformer, as measured from the inlet to the primary reformer to the outlet, was not to exceed 35 psi inclusive of catalyst tubes, inlet and outlet pigtails, inlet and outlet manifolds
- Exhaust gas from the gas turbine was to be limited and was not to increase

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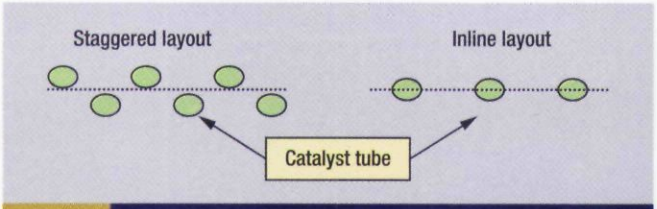


FIG. 4 Catalyst tube layout in staggered and online patterns.

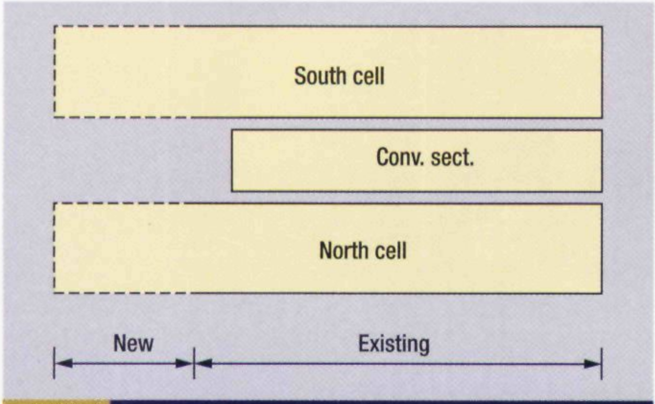


FIG. 5 Plan view of the reformer.

- Reformer was to operate at a lower methane slip (11.7% dry vs. 23% dry).

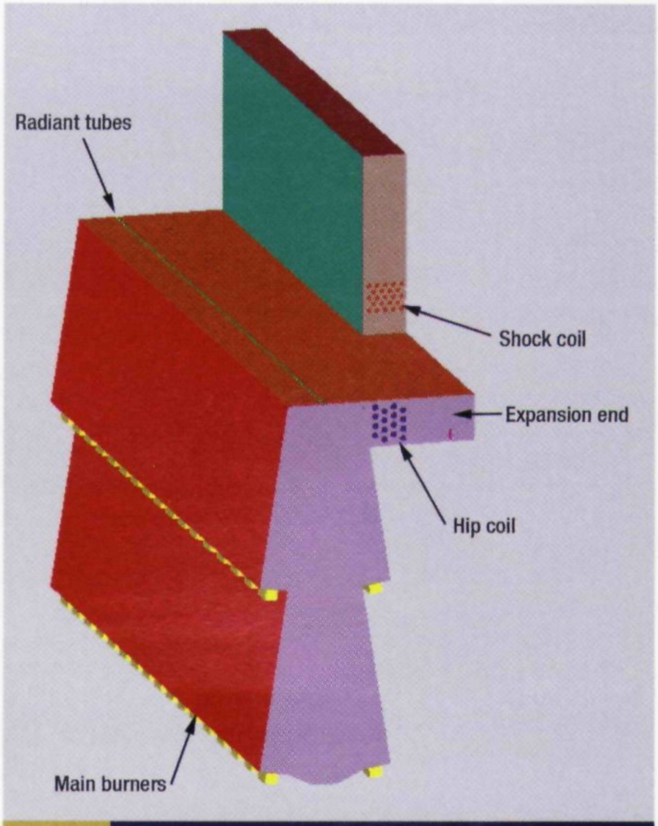


FIG. 6 Exterior geometry of model for the primary reformer.

Process scheme. A major change to the existing process scheme was the installation of a pre-reformer. This required the pre-heated mixed feed (~950–1,000°F) exiting the convection coil routed first to the pre-reformer and re-heated to 1,150°F in a new fired heater before entering the radiant section of the primary reformer. The new reformer outlet temperature is 1,470°F. The reformer heat balance is shown in Table 3.

Catalyst tubes. To meet the capacity objectives, the number, arrangement and metallurgy of the catalyst tubes was changed as shown in Table 2. The total number of tubes was increased to meet the pressure drop constraints.

The tube arrangement was changed from a staggered to an inline layout to improve heat flux distribution and ultimately reliability. The increase in reformer outlet temperature necessitated the upgrade from HK-40 to HP-microalloy tubes. Along with the tubes, the radiant inlet and outlet headers and pigtails were also upgraded to sustain the higher operating temperatures while the counterweight tube support system was replaced with constant spring-type supports (Fig. 4).

To accommodate the second phase of the expansion and minimize future capital investment, space for future tube addition was provided in the new configuration at minimal cost. This would prevent significant changes should the owner select to implement a Phase 2 project (Fig. 5).

Firebox extension. Extending the two radiant fireboxes by approximately 20 feet accommodated the change in catalyst tubes. The convection section did not require changes to meet Phase 1 performance from process and mechanical considerations. While this was a major benefit to the project cost and schedule, it raised another concern (Fig. 6). After the revamp, there would be a disparity in the firebox and convection lengths, which could potentially lead to adverse flue-gas flow patterns both in the firebox and the inlet to the convection section. To validate the proposed design, computational fluid dynamic (CFD) modeling was used to study the flue gas flow and heat transfer in the firebox and lower convection section. Results from this study were positive, as shown in Fig. 7. From the CFD study, the flow maldistribution effects to the convection section of the extended radiant section fireboxes would have minimal effects on furnace performance.

Mixed-feed coil. The existing mixed-feed coil was upgraded to meet the new flow and pressure drop requirements.

Burners. Forty new burners for the firebox extension, new fuel piping and partial replacement of the GTE ducts was necessary. Burner-tip replacement of the existing burners was also deemed necessary since the waste-gas flow and composition from ammonia synthesis loop was significantly different.

Air blower. For the expansion case, it was concluded that the available GTE for combustion was not sufficient and that supplemental air would be required. A combustion air blower was added to provide the required 10–20% incremental air. The additional air was injected into the main GTE duct well upstream of the burners to ensure good mixing. Along with this, appropriate safeguards were installed in the air duct to accommodate blower failure.

Pre-shutdown planning. When the process definition phase was complete, it was apparent that the extent of field work, which

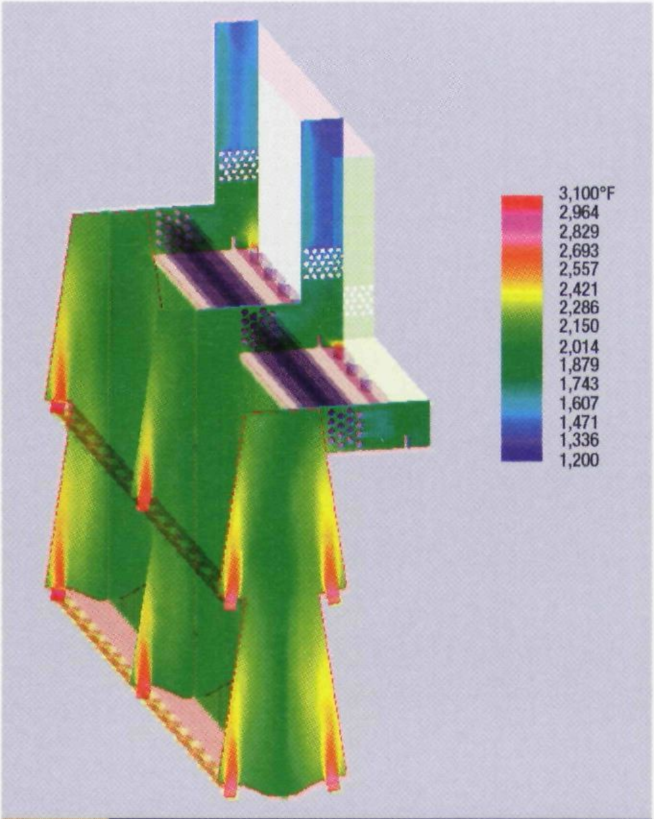


FIG. 7 Temperature contours in a vertical plane at center and ends of the firebox.

FIG. 8 Post-revamp view of the primary reformer.

included installing the new high-temperature furnace to re-heat the mixed feed from the pre-reformer, would not fit within the planned turnaround time (TAT). The project focus thus centered on schedule, material source and logistics:

Schedule. To meet the TAT, the maximum construction that could be accomplished safely while the unit was onstream was identified. In the furnace area, the primary reformer box extension was installed on new foundations with one end open, complete with refractory and burners. Once the unit was shut down and sufficiently cooled, the end wall was removed, and the two sections connected. The new mixed-feed re-heater furnace was also installed prior to the shutdown.

Material sourcing. Most of the materials involved in the revamp were either alloy or stainless. Demand for these products was at an all-time peak; thus, the project team had to make some early decisions on procuring tubes and fittings ahead of schedule.

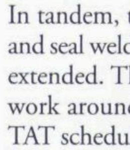
Logistics. Due to plant location, all of the construction materials and some specialized labor would have to be imported. Therefore, early delivery of critical components and selection of a construction contractor were essential to successfully support the schedule.

Shutdown activities. Once the plant was shut down, a scheduled period of 48 hours was allowed for cooldown, purging and safety release. Coordinated teams then moved to complete the construction work, which included removal and installation of:

- Catalyst tubes, inlet pigtails and headers, outlet pigtails and collection headers and transfer line
- Fuel lines, GTE ducting and the firebox end walls
- Mixed-feed coils
- Burner-replacement tips and tile repair.

In tandem, the firebox extension was closed with refractory work and seal welding, new burners installed and the penthouse structure extended. The last major activity was tie-ins. The total scheduled work around the furnace was completed nine days ahead of the TAT schedule.

Project overview. Despite the challenges of a tight project schedule (12 months from engineering to startup), application of a new converter technology, new pre-reforming section and major furnace retrofit, the plant was re-started in April 2005 as scheduled (Fig. 8). The plant has continuously operated at 1,050 stpd capacity since, enabling PCS Nitrogen to meet its market demand. **HP**



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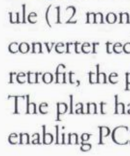

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